

UNCLASSIFIED

AD **297 988**

*Reproduced
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**

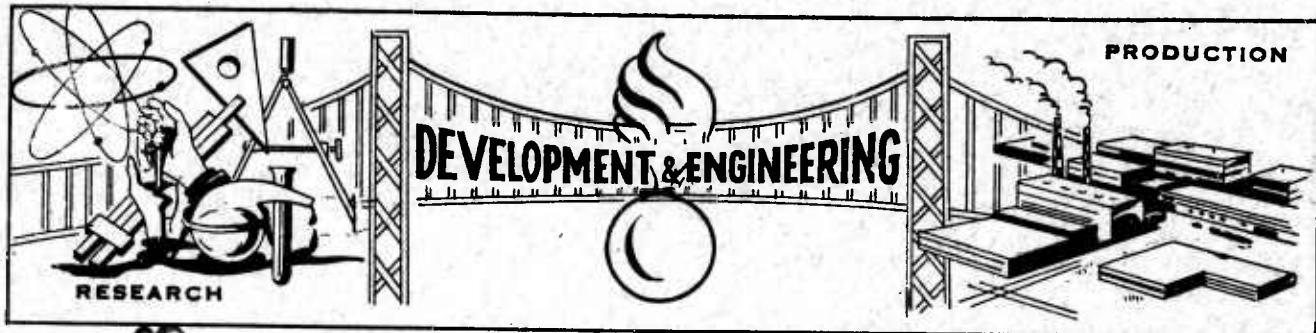


UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

297 988

63-2-5



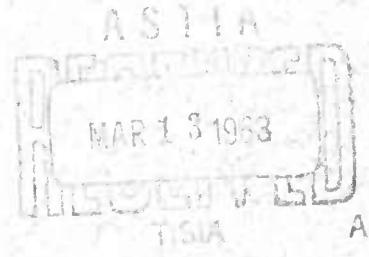
CATALOGED BY ASTIA
AS AD NO. 297988

TECHNICAL REPORT 3035

NOMOGRAPHS
FOR
INTERIOR BALLISTICS

BY

SIDNEY KRAVITZ



COPY NO. 19 OF 57

JANUARY 1963

PICATINNY ARSENAL - DOVER, NEW JERSEY

ASTIA AVAILABILITY NOTICE

Qualified requesters may obtain copies of this report
from ASTIA.

The findings in this report are not to be construed as
an official Department of the Army position.

The author would appreciate your comments.

SEND TO:

Commanding Officer
Picatinny Arsenal
Dover, New Jersey
ATTN: SMUPA-DR3 (Mr. Sidney Kravitz)

TECHNICAL REPORT 3035
AMMUNITION GROUP

NOMOGRAPHS
FOR
INTERIOR BALLISTICS

BY

SIDNEY KRAVITZ

JANUARY 1963

SUBMITTED BY: A. Berman

A. BERMAN
Chief, Special
Ammunition and
Analysis Section

REVIEWED BY: E.H. Buchanan

E.H. BUCHANAN
Chief, Artillery
Ammunition Laboratory

APPROVED BY: R.W. Vogel

R. W. VOGEL
Chief, Ammunition
Development Division

TABLE OF CONTENTS

| Section | | Page |
|-----------------------|----------------|-------|
| I | INTRODUCTION | 1 |
| II | SUMMARY | 1 |
| III | CONCLUSION | 2 |
| IV | RECOMMENDATION | 2 |
| V | STUDY | 3 |
| APPENDIX | | |
| A. Figures | | A1-A5 |
| TABLE OF DISTRIBUTION | | i |

SECTION I

INTRODUCTION

In April 1959 "Interior Ballistic Calculations with a Special Slide Rule" (Picatinny Arsenal Technical Report 2603) was published. This report presented the theory, design and use of a special slide rule for performing certain interior ballistic calculations. However, since slide rule calculations can always be duplicated with parallel-scale nomographs, it has been possible to construct a set of four nomographs for performing the same calculations.

The purpose of this report is to show how these nomographs are to be used. These calculations can be performed many times faster than is possible by any other method of calculation except the large-scale electronic computer

SECTION II

SUMMARY

A set of four nomographs are presented which will accurately perform certain interior ballistic calculations.

SECTION III

CONCLUSION

The nomographs presented have been checked against many standard guns and howitzers. It has been found that where pressure and charge are given, muzzle velocity can be accurately determined more rapidly than possible by any other method except large-scale electronic computers.

SECTION IV

RECOMMENDATION

That this set of interior ballistic nomographs be used for the rapid calculation of muzzle velocity.

SECTION V

STUDY

Use of The Nomographs

The following example shows how to use the interior ballistic nomographs when considering the 155mm Howitzer.

Quantities Given:

1. Propellant Weight, $C = 13.4875$ lbs.
2. Projectile Weight, $W = 95$ lbs.
3. Travel, $L = 115$ in.
4. Chamber Volume, $V_o = 795$ cu. in.
5. Pressure, $P = 36,530$ psi
6. Caliber, $D = 6.102$ in. (155mm)

Calculate The Following Quantities

1. Propellant Weight To Projectile Weight Ratio, $\epsilon = C/W = 13.4875/95 = 0.142$ lbs
2. Bore Area, $A = \frac{\pi D^2}{4} = \frac{\pi}{4} (6.102)^2 = 29.244$ in 2
3. Expansion Ratio, $X_m/X_o = 1 + \frac{AL}{V_o} = 1 + \frac{(29.244)(115)}{795} = 5.230$
4. Density Of Loading, $\Delta = \frac{27.68 C}{V_o} = \frac{27.68(13.4875)}{795} = 0.4696$, or 0.47 grams/cc.

NOMOGRAPH I

Line 1

Draw a straight line between $P = 36,530 \text{ psi}$ on the left scale to $\Delta = 0.47$ on the right scale. Note the intersection point of this line with the vertical center line.

Line 2

Draw a straight line between M_1 on the right scale and the intersection point on the vertical center line. Read $p = 0.40$ on the left scale. Also read $X_b = 2.2$ on left scale.

NOMOGRAPH II

Line 3

Draw a straight line between $\Delta = 0.47$ on the right scale and $(X_m/X_o) = 5.23$ on the center scale. Read $X_m = 7.0$ on the left scale. Proceed with Nomograph III only if $X_m > X_b$. In this case, $7.0 > 2.2$.

NOMOGRAPH III

Line 4

Connect $X_m = 7.0$ on the left scale to $p = 0.40$ on the center scale.
Read $\mu_m = 1.58$ on the right scale.

NOMOGRAPH IV

Line 5

Connect $\mu_m = 1.58$ on the left scale with $\epsilon = 0.142$ on the right scale. Note the intersection point with the center scale, then connect M_1 on the right scale with the intersection point on the center scale. Read

the muzzle velocity on the left scale, $V_m = 1,850 \text{ ft/sec.}$

Note:

The "p" center scale of Nomograph III is based on the assumption of zero starting pressure, propellant of constant burning surface, no co-volume excess, burning rate exponent equal to one, and ratio of specific heats equal to 1.3. A similar scale may be constructed for any other set of conditions. This will be the subject of a future report. However, it will be found that where pressure and charge are given and muzzle velocity is required, the nomographs will give accurate answers even when these conditions are not satisfied.

APPENDIX A

FIGURES

INTERIOR BALLISTICS NOMOGRAPHS

GIVEN (FOR 155 mm HOWITZER)

SIDNEY KRAUTZ

M1 PROPELLENT

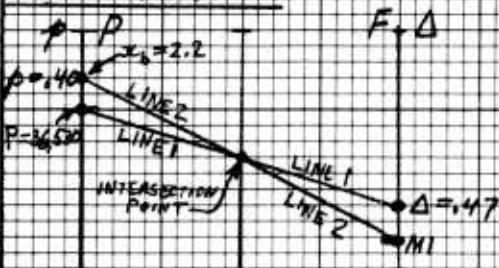
PROPELLENT TO PROJECTILE WEIGHT RATIO, $\epsilon = .142$

DENSITY OF LOADING, GRAMS/CC, $\Delta = .47$

MAXIMUM PRESSURE, PSI, $P = 36,530$

EXPANSION RATIO, $X_m/X_0 = 5.23$

NOMOGRAPH I



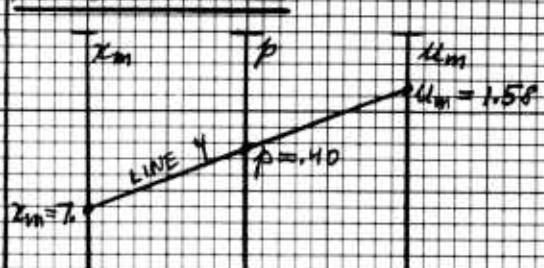
LINE 1

CONNECT $P=36,530$ TO $\Delta = .47$
NOTE INTERSECTION POINT.

LINE 2

CONNECT M1 TO INTERSECTION POINT.
READ $\epsilon = .40$. READ $X_m/X_0 = 2.2$

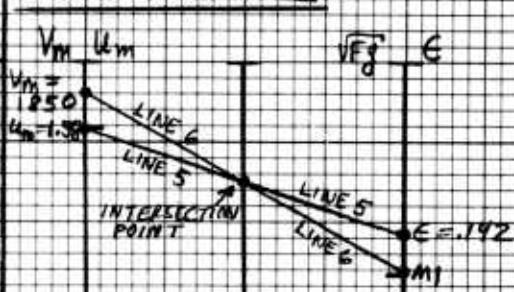
NOMOGRAPH III



LINE 4

CONNECT $X_m/X_0 = 7.0$ TO $\epsilon = .40$.
READ $V_m = 1.58$

NOMOGRAPH IV



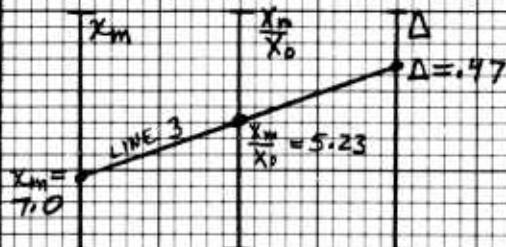
LINE 5

CONNECT $V_m = 1.58$ TO $\epsilon = .47$
NOTE INTERSECTION POINT.

LINE 6

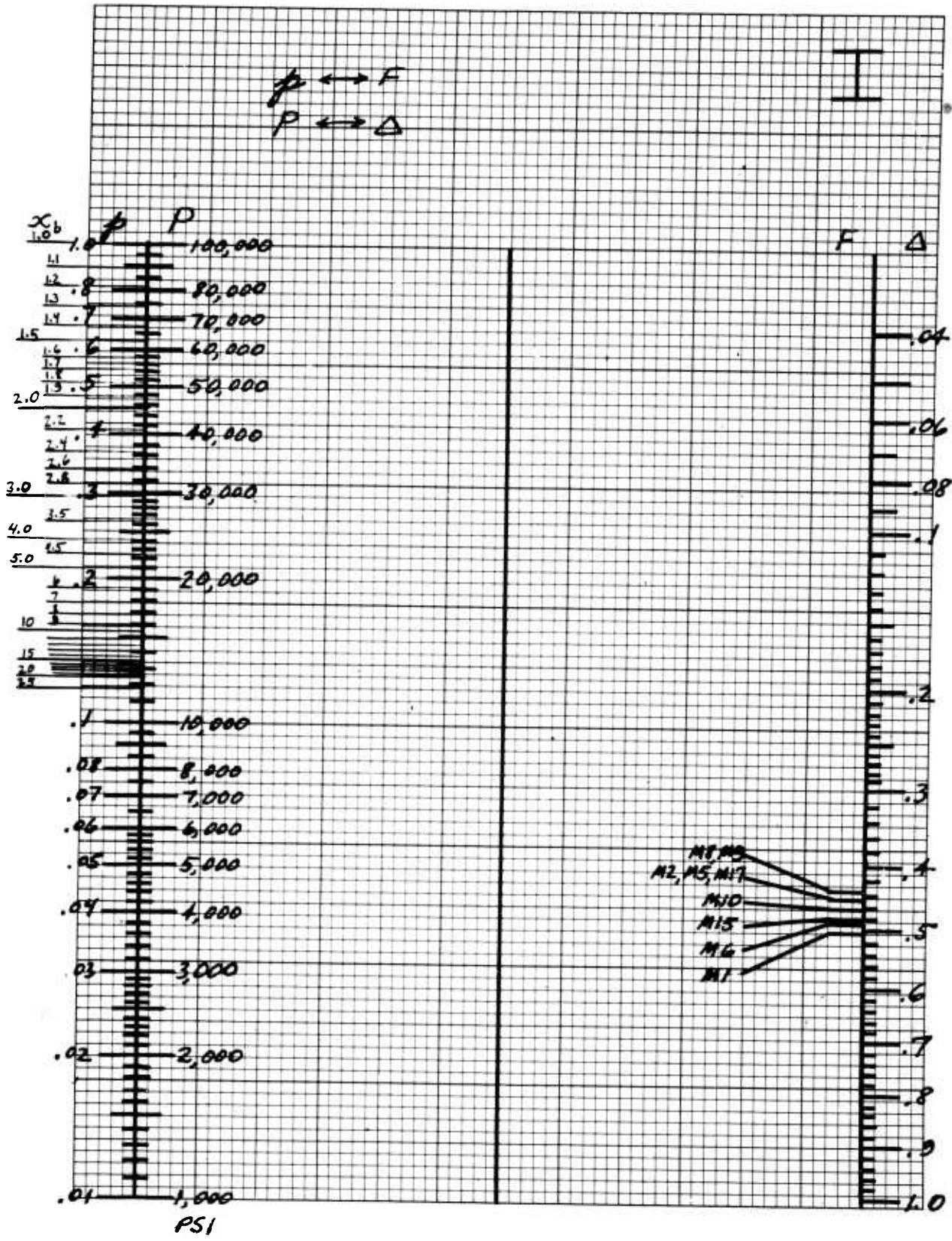
CONNECT M1 TO INTERSECTION POINT.
READ MUZZLE VELOCITY,
 $V_m = 1850$ FT/SEC

NOMOGRAPH II

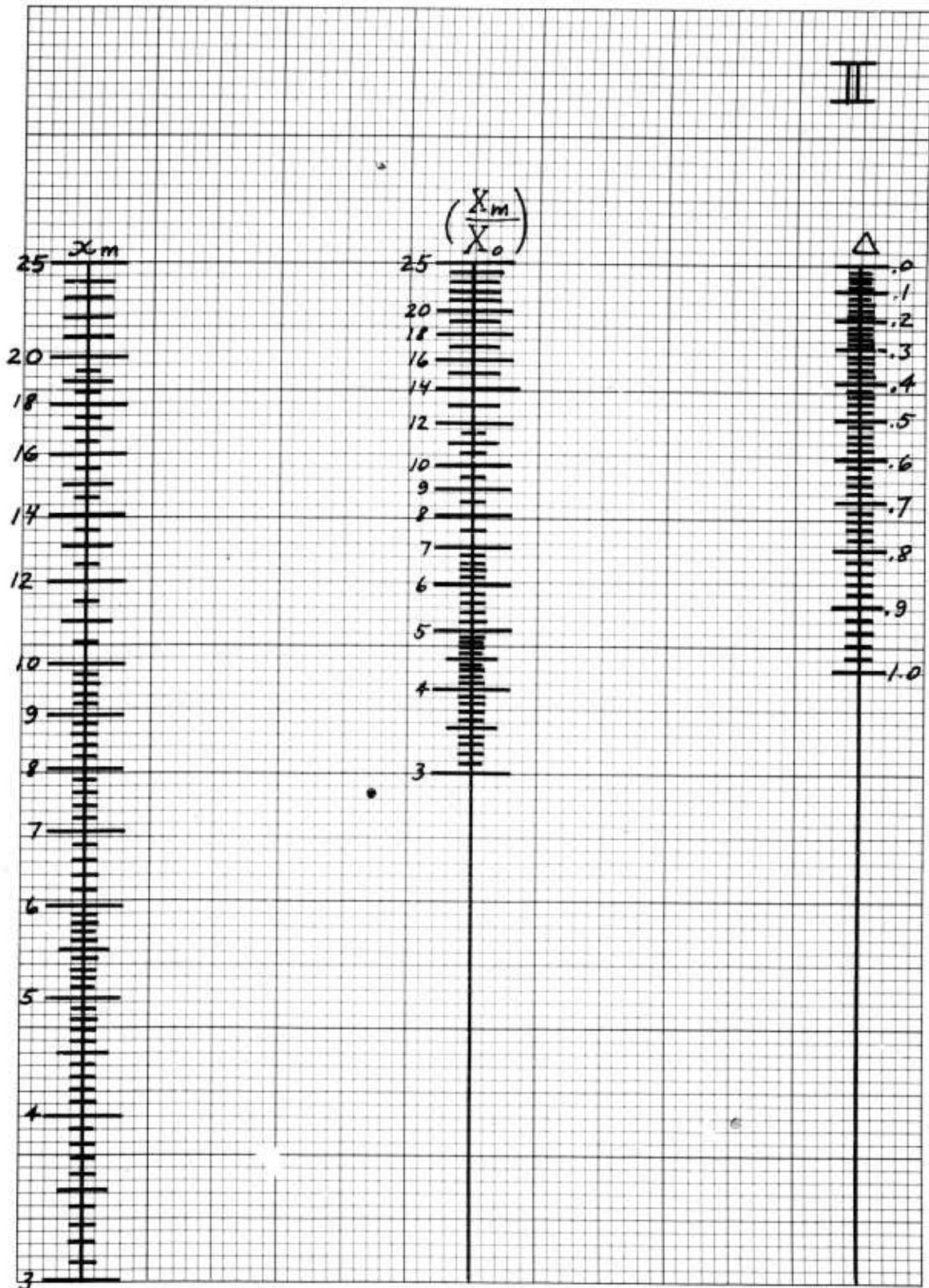


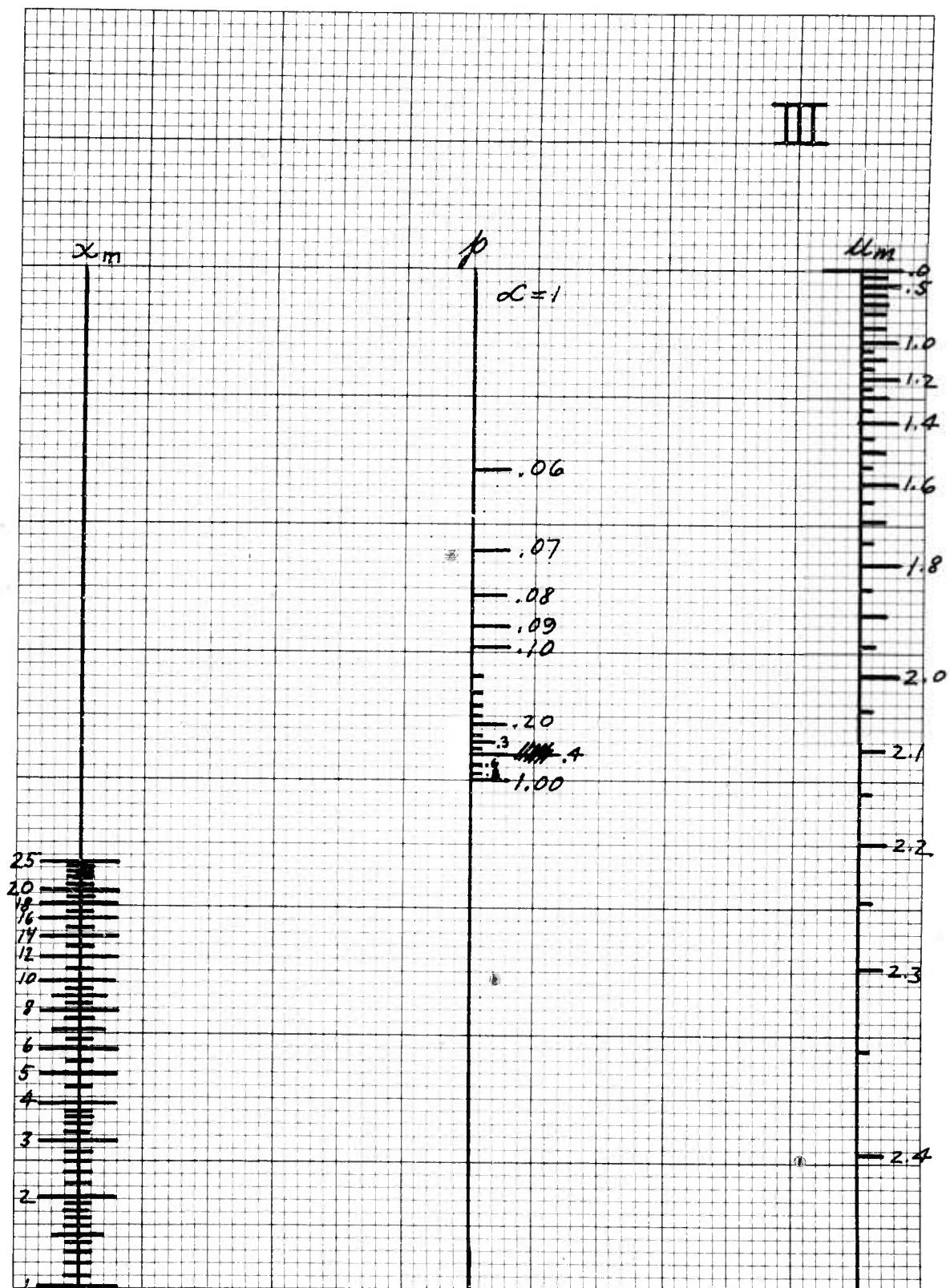
LINE 3

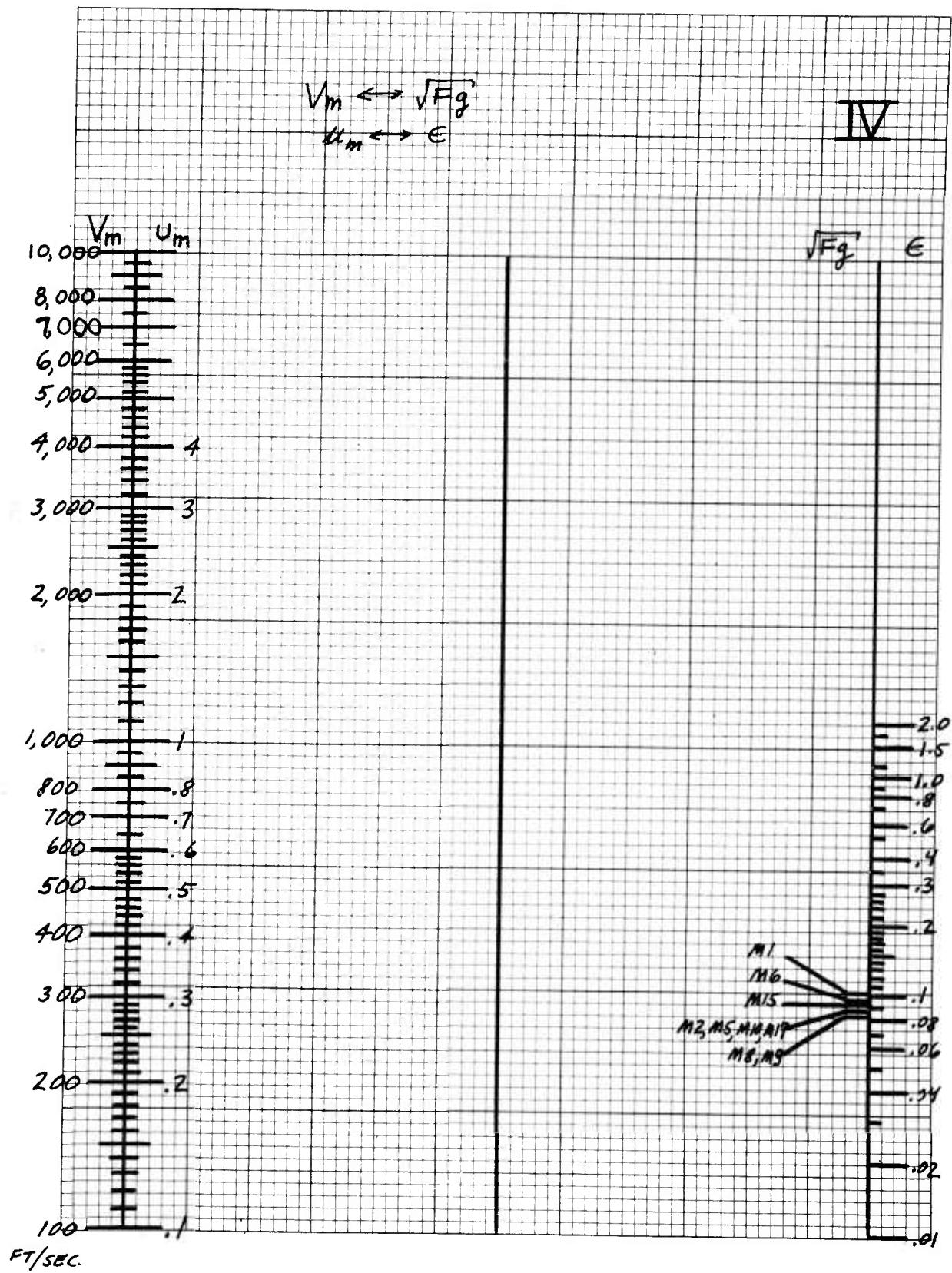
CONNECT $\Delta = .47$ TO $X_m/X_0 = 5.23$.
READ $X_m/X_0 = 7.0$. PROCEED
ONLY IF $X_m/X_0 > X_b$. IN THIS
CASE $7.0 > 2.2$.



II







ABSTRACT DATA

ABSTRACT DATA

AD _____ Accession No. _____

Picatinny Arsenal, Dover, N.J.

NOMOGRAPHS FOR INTERIOR BALLISTICS

Sidney Kravitz

Technical Report 3035, January 1963
12pp, figures.

Unclassified Report from the Artillery Ammunition
Laboratory, Ammunition Group.

A set of four nomographs are presented which will
accurately perform certain interior ballistic calcula-
tions many times faster than is possible by any other
method except the large-scale computer.

The study describes how to use these nomographs to
accurately determine muzzle velocity for the 155mm
howitzer when pressure and charge are given.

UNCLASSIFIED

1. Interior ballistic -- Calculations.
2. Muzzle velocity -- 155mm Howitzer.

- I. Kravitz, Sidney
II. Nomographs

UNITERMS

Nomograph
Calculation
155mm
Muzzle velocity
Ballistics
Kravitz, S.

| | | | |
|--|---|--|---|
| AD _____ Accession No. _____ | UNCLASSIFIED | AD _____ Accession No. _____ | UNCLASSIFIED |
| Picatinny Arsenal, Dover, New Jersey | | Picatinny Arsenal, Dover, New Jersey | |
| NOMOGRAPHS FOR INTERIOR BALLISTICS | | NOMOGRAPHS FOR INTERIOR BALLISTICS | |
| Sidney Kravitz | | Sidney Kravitz | |
| Technical Report 3035, January 1963, 12 pp, figures. Unclassified Report from the Artillery Ammunition Laboratory, Ammunition Group. | A set of four nomographs are presented which will accurately perform certain interior ballistic calculations many times faster than is possible by any other method except the large-scale computer. The study describes how to use these nomographs to accurately determine muzzle velocity for the 155 mm howitzer when pressure and charge are given. | Technical Report 3035, January 1963, 12 pp, figures. Unclassified Report from the Artillery Ammunition Laboratory, Ammunition Group. | A set of four nomographs are presented which will accurately perform certain interior ballistic calculations many times faster than is possible by any other method except the large-scale computer. The study describes how to use these nomographs to accurately determine muzzle velocity for the 155 mm howitzer when pressure and charge are given. |

| | | | |
|--|---|--|---|
| AD _____ Accession No. _____ | UNCLASSIFIED | AD _____ Accession No. _____ | UNCLASSIFIED |
| Picatinny Arsenal, Dover, New Jersey | | Picatinny Arsenal, Dover, New Jersey | |
| NOMOGRAPHS FOR INTERIOR BALLISTICS | | NOMOGRAPHS FOR INTERIOR BALLISTICS | |
| Sidney Kravitz | | Sidney Kravitz | |
| Technical Report 3035, January 1963, 12 pp, figures. Unclassified Report from the Artillery Ammunition Laboratory, Ammunition Group. | A set of four nomographs are presented which will accurately perform certain interior ballistic calculations many times faster than is possible by any other method except the large-scale computer. The study describes how to use these nomographs to accurately determine muzzle velocity for the 155 mm howitzer when pressure and charge are given. | Technical Report 3035, January 1963, 12 pp, figures. Unclassified Report from the Artillery Ammunition Laboratory, Ammunition Group. | A set of four nomographs are presented which will accurately perform certain interior ballistic calculations many times faster than is possible by any other method except the large-scale computer. The study describes how to use these nomographs to accurately determine muzzle velocity for the 155 mm howitzer when pressure and charge are given. |

AD _____ Accession No. _____
Picatinny Arsenal, Dover, New Jersey

NOMOGRAPHS FOR INTERIOR BALLISTICS

Sidney Kravitz

Technical Report 3035, January 1963, 12 pp., figures. Unclassified Report from the Artillery Ammunition Laboratory, Ammunition Group.

A set of four nomographs are presented which will accurately perform certain interior ballistic calculations many times faster than is possible by any other method except the large-scale computer.

The study describes how to use these nomographs to accurately determine muzzle velocity for the 155 mm howitzer when pressure and charge are given.

UNCLASSIFIED

AD _____ Accession No. _____
Picatinny Arsenal, Dover, New Jersey

NOMOGRAPHS FOR INTERIOR BALLISTICS

Sidney Kravitz

Technical Report 3035, January 1963, 12 pp., figures. Unclassified Report from the Artillery Ammunition Laboratory, Ammunition Group.

A set of four nomographs are presented which will accurately perform certain interior ballistic calculations many times faster than is possible by any other method except the large-scale computer.

The study describes how to use these nomographs to accurately determine muzzle velocity for the 155 mm howitzer when pressure and charge are given.

UNCLASSIFIED

AD _____ Accession No. _____
Picatinny Arsenal, Dover, New Jersey

NOMOGRAPHS FOR INTERIOR BALLISTICS

Sidney Kravitz

Technical Report 3035, January 1963, 12 pp., figures. Unclassified Report from the Artillery Ammunition Laboratory, Ammunition Group.

A set of four nomographs are presented which will accurately perform certain interior ballistic calculations many times faster than is possible by any other method except the large-scale computer.

The study describes how to use these nomographs to accurately determine muzzle velocity for the 155 mm howitzer when pressure and charge are given.

UNCLASSIFIED

AD _____ Accession No. _____
Picatinny Arsenal, Dover, New Jersey

NOMOGRAPHS FOR INTERIOR BALLISTICS

Sidney Kravitz

Technical Report 3035, January 1963, 12 pp., figures. Unclassified Report from the Artillery Ammunition Laboratory, Ammunition Group.

A set of four nomographs are presented which will accurately perform certain interior ballistic calculations many times faster than is possible by any other method except the large-scale computer.

The study describes how to use these nomographs to accurately determine muzzle velocity for the 155 mm howitzer when pressure and charge are given.

UNCLASSIFIED

| | | | |
|--|--------------|--|--------------|
| AD _____ Accession No. _____ | UNCLASSIFIED | AD _____ Accession No. _____ | UNCLASSIFIED |
| Picatinny Arsenal, Dover, New Jersey | | Picatinny Arsenal, Dover, New Jersey | |
| NOMOGRAPHS FOR INTERIOR BALLISTICS | | NOMOGRAPHS FOR INTERIOR BALLISTICS | |
| Sidney Kravitz | | Sidney Kravitz | |
| Technical Report 3035, January 1963, 12 pp, figures. Unclassified Report from the Artillery Ammunition Laboratory, Ammunition Group. | | Technical Report 3035, January 1963, 12 pp, figures. Unclassified Report from the Artillery Ammunition Laboratory, Ammunition Group. | |
| A set of four nomographs are presented which will accurately perform certain interior ballistic calculations many times faster than is possible by any other method except the large-scale computer. | | A set of four nomographs are presented which will accurately perform certain interior ballistic calculations many times faster than is possible by any other method except the large-scale computer. | |
| The study describes how to use these nomographs to accurately determine muzzle velocity for the 155 mm howitzer when pressure and charge are given. | | The study describes how to use these nomographs to accurately determine muzzle velocity for the 155 mm howitzer when pressure and charge are given. | |
| UNCLASSIFIED | | UNCLASSIFIED | |
| AD _____ Accession No. _____ | UNCLASSIFIED | AD _____ Accession No. _____ | UNCLASSIFIED |
| Picatinny Arsenal, Dover, New Jersey | | Picatinny Arsenal, Dover, New Jersey | |
| NOMOGRAPHS FOR INTERIOR BALLISTICS | | NOMOGRAPHS FOR INTERIOR BALLISTICS | |
| Sidney Kravitz | | Sidney Kravitz | |
| Technical Report 3035, January 1963, 12 pp, figures. Unclassified Report from the Artillery Ammunition Laboratory, Ammunition Group. | | Technical Report 3035, January 1963, 12 pp, figures. Unclassified Report from the Artillery Ammunition Laboratory, Ammunition Group. | |
| A set of four nomographs are presented which will accurately perform certain interior ballistic calculations many times faster than is possible by any other method except the large-scale computer. | | A set of four nomographs are presented which will accurately perform certain interior ballistic calculations many times faster than is possible by any other method except the large-scale computer. | |
| The study describes how to use these nomographs to accurately determine muzzle velocity for the 155 mm howitzer when pressure and charge are given. | | The study describes how to use these nomographs to accurately determine muzzle velocity for the 155 mm howitzer when pressure and charge are given. | |
| UNCLASSIFIED | | UNCLASSIFIED | |

TABLE OF DISTRIBUTION

TABLE OF DISTRIBUTION

| | Copy Number |
|--|----------------------|
| 1. Commanding Officer Picatinny Arsenal Dover, New Jersey ATTN: SMUPA-VA6 SMUPA-DR3 | 1-5 |
| 2. Commanding General U.S. Army Materiel Command Washington 25, D.C. ATTN: AMCRD-RS, Ballistics | 6 |
| 3. Commanding General U.S. Army Missile Command Redstone Arsenal, Huntsville, Alabama ATTN: MTP TRT Technical Library | 7 8 9 |
| 4. Commanding Officer Redstone Arsenal Alabama | 10 |
| 5. Commanding General U.S. Army Test and Evaluation Command Aberdeen Proving Ground, Maryland ATTN: BRL, Interior Ballistics Lab OTIO D & PS Technical Library | 11 12 13 14 |
| 6. Commander Armed Services Technical Information Agency Arlington Hall Station Arlington 12, Virginia | 15-24 |
| 7. Director Jet Propulsion Laboratory California Institute of Technology 4800 Oak Grove Drive Pasadena 3, California ATTN: Dr. L. G. Dunn | 25 |

TABLE OF DISTRIBUTION (Cont'd)

| | Copy Number |
|--|--------------------|
| 8. Arthur D. Little, Inc. 15 Acorn Park Cambridge 40, Massachusetts | 26 |
| 9. Armour Research Foundation Technology Center Chicago 16, Illinois | 27 |
| 10. Commanding Officer Naval Proving Ground Dahlgren, Virginia | 28 |
| 11. Commander U.S. Naval Ordnance Laboratory 8050 Georgia Avenue White Oak Silver Spring 19, Maryland | 29 |
| 12. Commanding General Headquarters Air Development Command Wright Patterson Air Force Base Dayton, Ohio | 30 |
| 13. Headquarters U.S. Air Force DCS/D AFDRD/AR Washington 25, D.C. | 31 |
| 14. Director Air University Maxwell Air Force Base Montgomery, Alabama ATTN: Air University Library | 32 |
| 15. Dept. of Ordnance and Gunnery U.S. Military Academy West Point, New York | 33 |

TABLE OF DISTRIBUTION (Cont'd)

| | Copy Number |
|--|-------------|
| 16. President Marine Corps Equipment Board Quantico, Virginia | 34 |
| 17. Director Marine Corps Development Center Marine Corps School Quantico, Virginia | 35 |
| 18. Solid Propellant Information Agency Applied Physics Laboratory The Johns Hopkins University Silver Spring, Maryland | 36 |
| 19. Sandia Corporation Albuquerque New Mexico | 37 |
| 20. Yale University New Haven 11, Connecticut ATTN: Dr. H. L. Schultz | 38 |
| 21. Bendix Aviation Corporation Eclipse Pioneer Division Teterboro, New Jersey ATTN: W.C. Teague | 39 |
| 22. Commanding Officer Frankford Arsenal Bridge and Tacony Streets Philadelphia 37, Pa. | 40 |
| 23. Commanding Officer Watertown Arsenal Watertown 72, Massachusetts | 41 |
| 24. Catholic University Washington, D.C. ATTN: K.J. Laidler | 42 |

TABLE OF DISTRIBUTION (Cont'd)

Copy Number

| | |
|---|----------------------------|
| 25. Canadian Armaments Research & Development Establishment Valcartier, Quebec Canada | 43 |
| 26. Chief Bureau of Aeronautics Dept of the Navy Washington 25, D.C. ATTN: Armament Division | 44 |
| 27. Department of the Navy Bureau of Ships Research and Development Material Development Division Washington 25, D.C. | 45 |
| 28. Chief Bureau of Ordnance Dept of the Navy Washington 25, D.C. ATTN: Re2 ReXa Re4 Re8 Re3 | 46 47 48 49 50 |
| 29. Commander Naval Ordnance Test Station Inyokern China Lake, California | 51 |
| 30. Princeton University Princeton, New Jersey ATTN: Dr. M.G. White | 52 |
| 31. Midwest Research Institute 425 Volker Boulevard Kansas City 10, Missouri ATTN: Librarian | |

TABLE OF DISTRIBUTION

| | Copy Number |
|--|-------------|
| 32. New York University 25 Waverly Place New York 3, N.Y. ATTN: R.D. Richtinger | 54 |
| 33. Rohm and Haas Company Redstone Arsenal Research Division Huntsville, Alabama ATTN: Librarian | 55 |
| 34. Thiokol Chemical Corporation Redstone Division Huntsville, Alabama ATTN: Technical Director | 56 |
| 35. Commanding Officer Diamond Ordnance Fuze Laboratories Connecticut Van Ness Avenues Washington 25, D.C. ATTN: Technical Reference Section | 57 |